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Wisconsinan stratigraphy at northern margin of Strait of Georgia, southern Cortes Island and vicinity, British Columbia

H.P. Trettin

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Abstract: About 130 m of Wisconsinan strata, exposed on the northern margin of the Strait of Georgia record climate-controlled, cyclical, predominantly marine deposition. Position below sea level of the base of the sediments (>80 m in a well) is attributed to pre-Wisconsinan glacial erosion within the strait. The early Wisconsinan Semiahmoo Glaciation produced advance deposits (Cortes Sand, new formation) and glaciomarine sediments and till (Marina Island Diamict, new). The middle Wisconsinan Olympia Nonglacial Interval is represented by the upper member of the Cowichan Head Formation, which unconformably overlies the diamict. The late Wisconsinan Fraser Glaciation generated advance deposits (Quadra Sand); glaciomarine sediments (Mansons Landing Diamict, new); inferred till and glaciomarine sediments represented by boulder lag only; subaqueous delta sediments; and again inferred glaciomarine sediments, winnowed to boulder lag during the isostasy-driven final emergence.

Résumé : La rive septentrionale du détroit de Georgia recèle des strates wisonsiniennes d'une épaisseur de 130 m qui témoignent d'une sédimentation cyclique, sujette aux variations climatiques et ayant eu lieu surtout en milieu marin. La base de la section est située sous le niveau de la mer (à plus de 80 m de profondeur dans un puits), ce que l'on attribue à une érosion glaciaire pré-wisconsinienne dans le détroit. La Glaciation de Semiahmoo du Wisconsin inférieur est à l'origine de dépôts d'avancée (une nouvelle formation, le Sable de Cortes) ainsi que de sédiments glaciomarins et de tills (une nouvelle unité, le Diamicton de Marina Island). L'intervalle non glaciaire d'Olympia du Wisconsin moyen est représenté par le membre supérieur de la Formation de Cowichan Head, qui repose en discordance sur le diamicton. La Glaciation de Fraser du Wisconsin supérieur a produit des dépôts d'avancée (le Sable de Quadra); des sédiments glaciomarins (le Diamicton de Mansons Landing, nouvelle unité); ce que l'on suppose être du till et des sédiments glaciomarins représentés uniquement par un résidu de blocs; des sédiments de delta subaquatique; et, enfin, ce que l'on croit être des sediments glaciomarins qui ont été vannés pour former un résidu de blocs pendant la phase finale d'émersion isostasique.

INTRODUCTION

The report area, located at approximately 125°W longitude, 50°N latitude, comprises southern Cortes, Marina, and northwestern Hernando islands. Cortes Island is accessible by ferry from Campbell River on Vancouver Island via Quadra Island (Fig. 1a).

Previous and current investigations

The Quaternary succession in the broader region has been mapped by Dawson (1887), Bancroft (1913), and Roddick and Woodsworth (1977) in the course of regional projects of the Geological Survey of Canada, concerned mainly with bedrock geology. J.T. Fyles recognized the widespread occurrence of the Quadra Sand (late Wisconsinan) and made paleocurrent determinations (included in Fig. 2 *in* Clague (1977)). He also obtained a relatively old radiocarbon date on fossil wood in an isolated outcrop on Marina Island (Olson and Broecker, 1961, p. 147; Table 6 *in* Clague, 1977). A restudy of the postglacial rebound in the Georgia Depression, based on modelling and radiocarbon determinations, has been carried out by T.S. James and colleagues in recent years (James et al., 2000, 2002; Clague and James, 2002). In 2001 three marine shell collections were obtained from Cortes Island, including two from the report area (T.S. James, pers. comm., 2003).

The results reported here were obtained by the writer between 1988 and 2003.

Geological setting and physiography

The oldest rocks in the study area are sedimentary and volcanic strata of the Wrangellia Terrane, ranging from Late Triassic to Middle Jurassic (Parson Bay and Harbledown formations and Bonanza Group; Trettin and Roddick (2002)). They are intruded by granitoid rocks of the southwestern Coast Plutonic Complex — mainly tonalite and granodiorite with lesser quartz diorite and granite, and abundant dykes of generally more mafic composition. Isotopic determinations from adjacent areas range from Late Jurassic to Late Cretaceous. Sediments of Cretaceous or Tertiary age are not preserved but strata of Pleistocene age are widely distributed.

The northern limit of the report area is defined by the Uganda lineament, named for the passage between Cortes and Marina islands (Fig. 1b). Bedrock is widely exposed north of this boundary. The Pleistocene succession there is mostly above sea level, but too poorly exposed for systematic study. Bedrock is absent and the base of the Pleistocene succession lies below sea level south of the lineament, but the exposures are sufficient to piece together a stratigraphic column (Fig. 2, 3). The position of the base of these sediments below sea level is confirmed by logs of water wells on southern Cortes Island, published on the Internet by the British Columbia Ministry of Water, Land and Air Protection (Groundwater Portal). None has reached bedrock although one (BCGS 092K006133, well 2, Potlatch Road) extends as much as much as 80 m below sea level. A well on Hernando Island has penetrated 25 m of sediments below sea level (Clague, 1977). Apart from this important information, the well logs are unsuited for stratigraphic purposes.

Two features of the lineament require further explanation. 1) It is defined by the nearest outcrops of bedrock, which seem to line up. Apart from the Uganda Passage itself, however, linear topographic features — common elsewhere on the island — are absent. 2) On the index map (Fig. 1b) the lineament has been projected across Quaternary strata just north of Mansons Landing although it is not seen there. The sediments at that locality represent a Holocene spit that presumably drapes over the contact between bedrock and Pleistocene strata.

The Uganda lineament is bordered on the northeast by an extensive belt of biotite granodiorite and is subparallel to faults forming the northeastern boundary of that belt. This relation may indicate that the lineament represents a basement fault, reactivated during Pleistocene isostatic adjustments. Convincing geomorphic evidence for such reactivation, however, is lacking. More likely, the lineament represents the northeastern limit of deep, pre-Wisconsinan glacial erosion within the Strait of Georgia, which may have been controlled by bedrock lithology or an inactive, older fault. The latter interpretation is supported by the regional picture: the base of the Pleistocene sediments is commonly below sea level at the margins of the Strait of Georgia (including Savary and southern Quadra islands, Fig. 1a), but no faults or lineaments have been recorded elsewhere (cf. Fig. 2 *in* Clague, 1977).

The structure of the Pleistocene sediments is best known on Marina Island (Fig. 1c; vertical exaggeration: x10). A homocline in the southern part of the island, defined by the top of a resistant unit (3A), dips approximately 011/01 and is bordered on the north-northeast by a slightly warped, nearly horizontal panel. Because of the absence of a suitable marker, a cross-section has not been constructed for Cortes Island. The distribution of the different units indicates a structural high on the southeastern coast (near locality p) and, farther northwest, a gentle homocline, aligned with the homocline on southern Marina Island.

Marina and southern Cortes islands form elevated plains that are bounded by precipitous seacliffs. From the top of these cliffs, which are between 10 m and some 30 m above sea level, the surfaces rise gently to elevations above 50 m or 80 m, respectively. While most of the Pleistocene strata are concealed by Holocene soil and vegetation, exposures up to 50 m in stratigraphic thickness are present locally on the cliffs. Additional exposures are provided by excavations on the top of the elevated plain of southern Cortes Island.

Hernando Island is mostly covered by Holocene soil and vegetation. An excellent exposure of Pleistocene strata on the northwestern coast is included in this report. The study of the northeastern coast, where both Mesozoic bedrock and Pleistocene sediments are exposed, has not yet been completed.

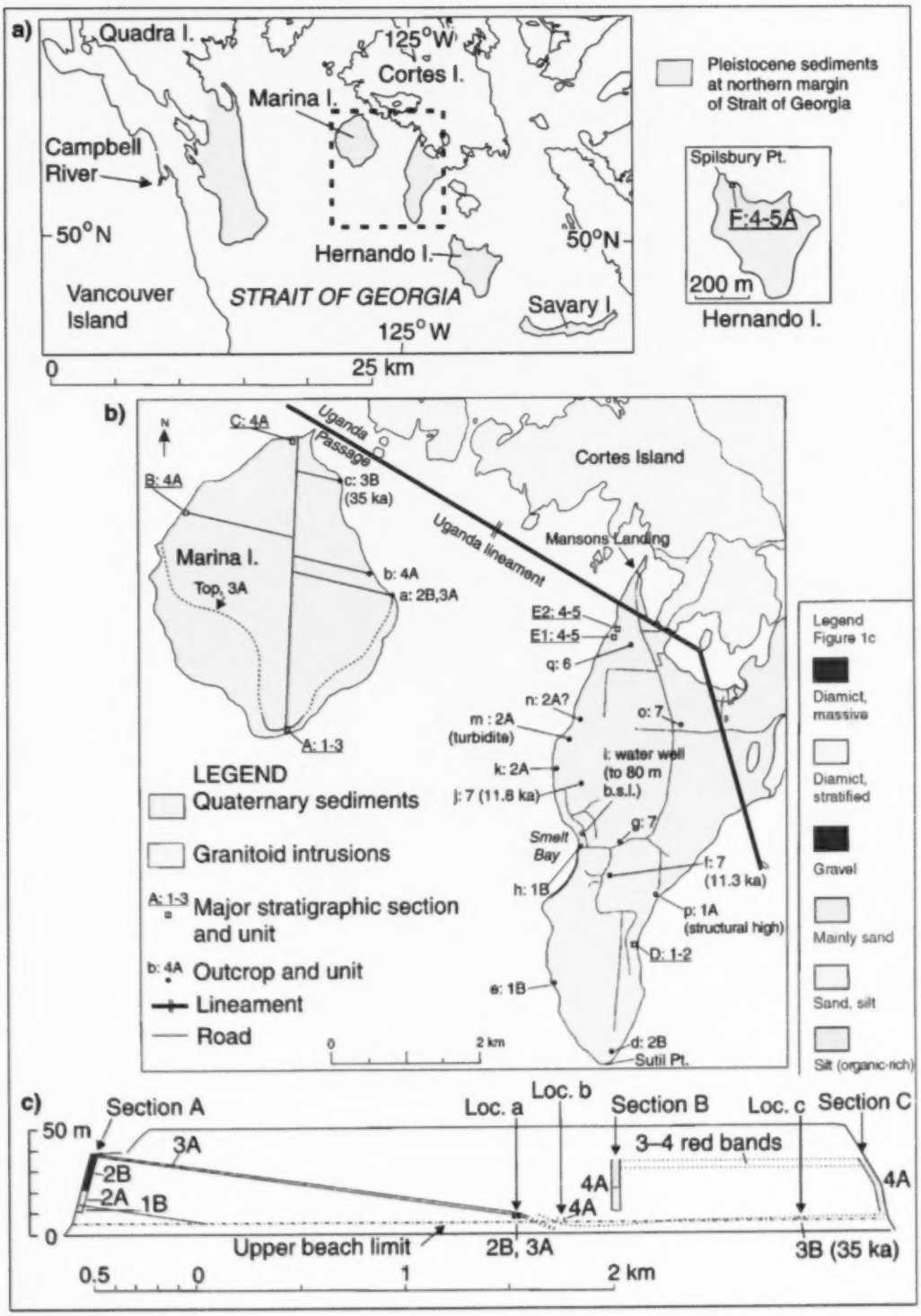


Figure 1. *Maps and cross-section:* ***a)*** *setting of report area;* ***b)*** *index map of main study area;* ***c)*** *structural cross-section of Marina Island; Loc. = locality.*

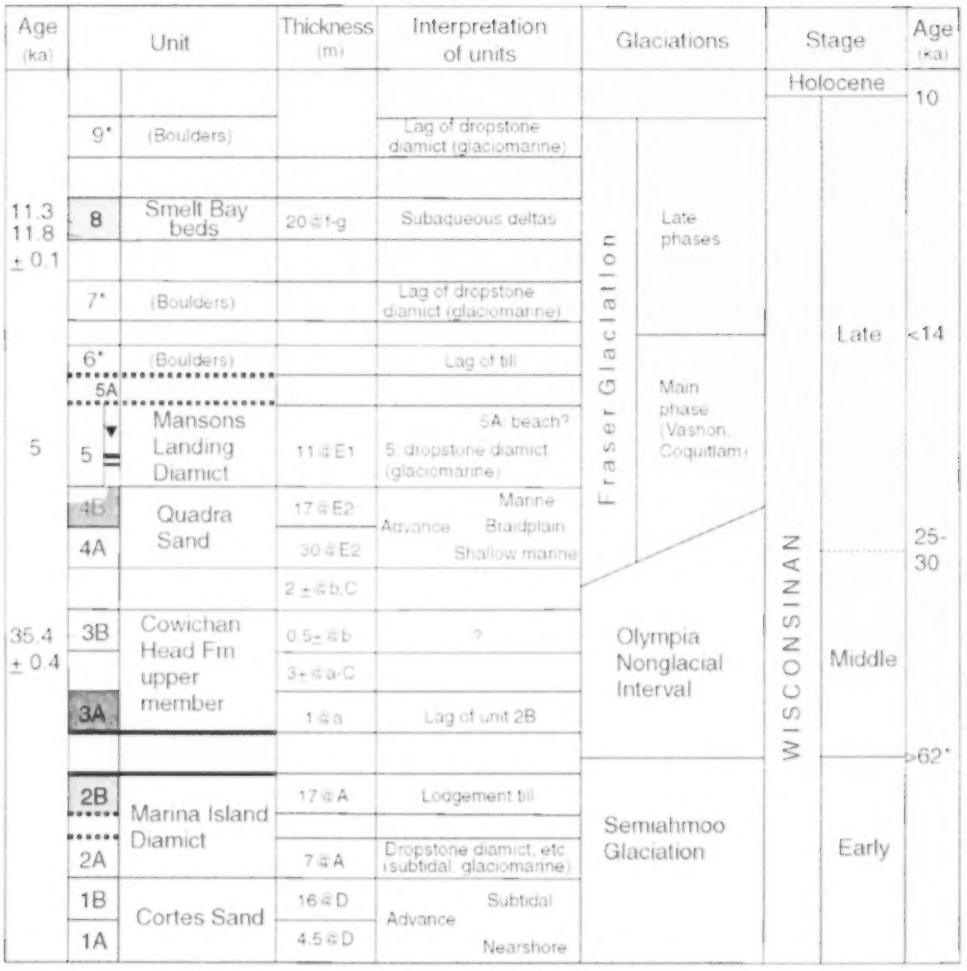
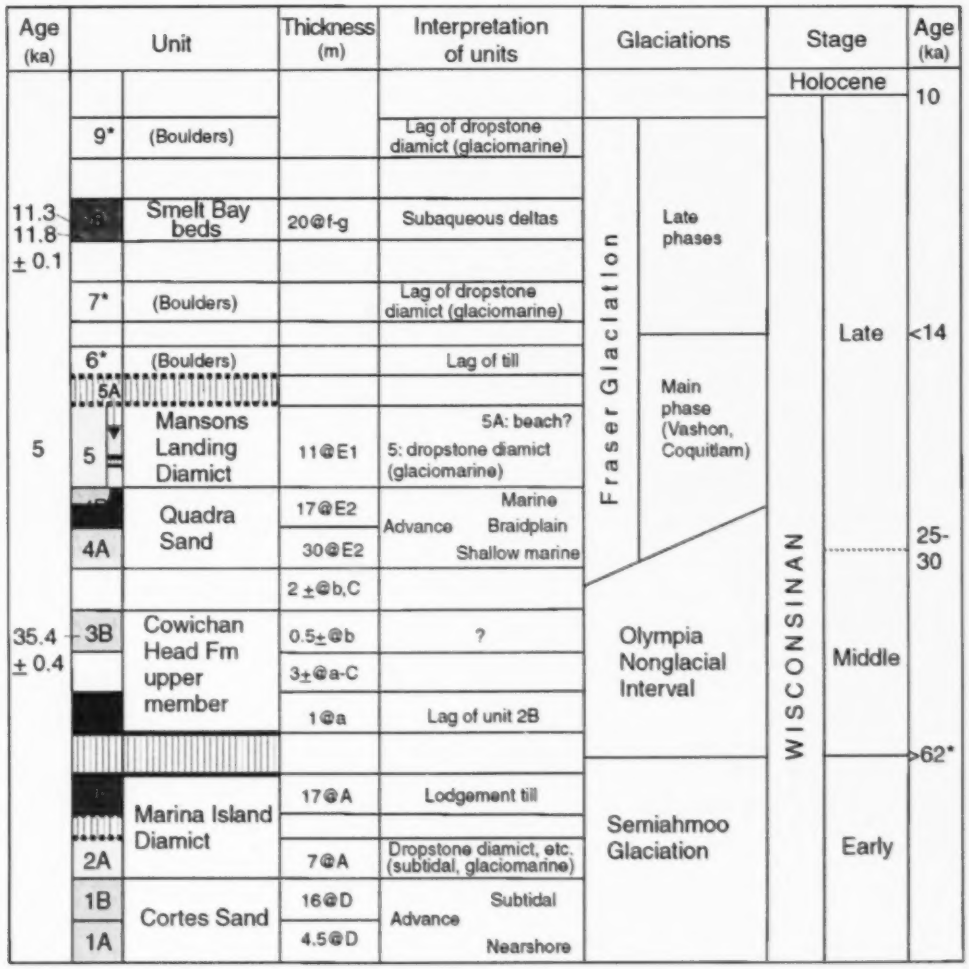


Figure 2. *Table of formations (time axis not to scale).*



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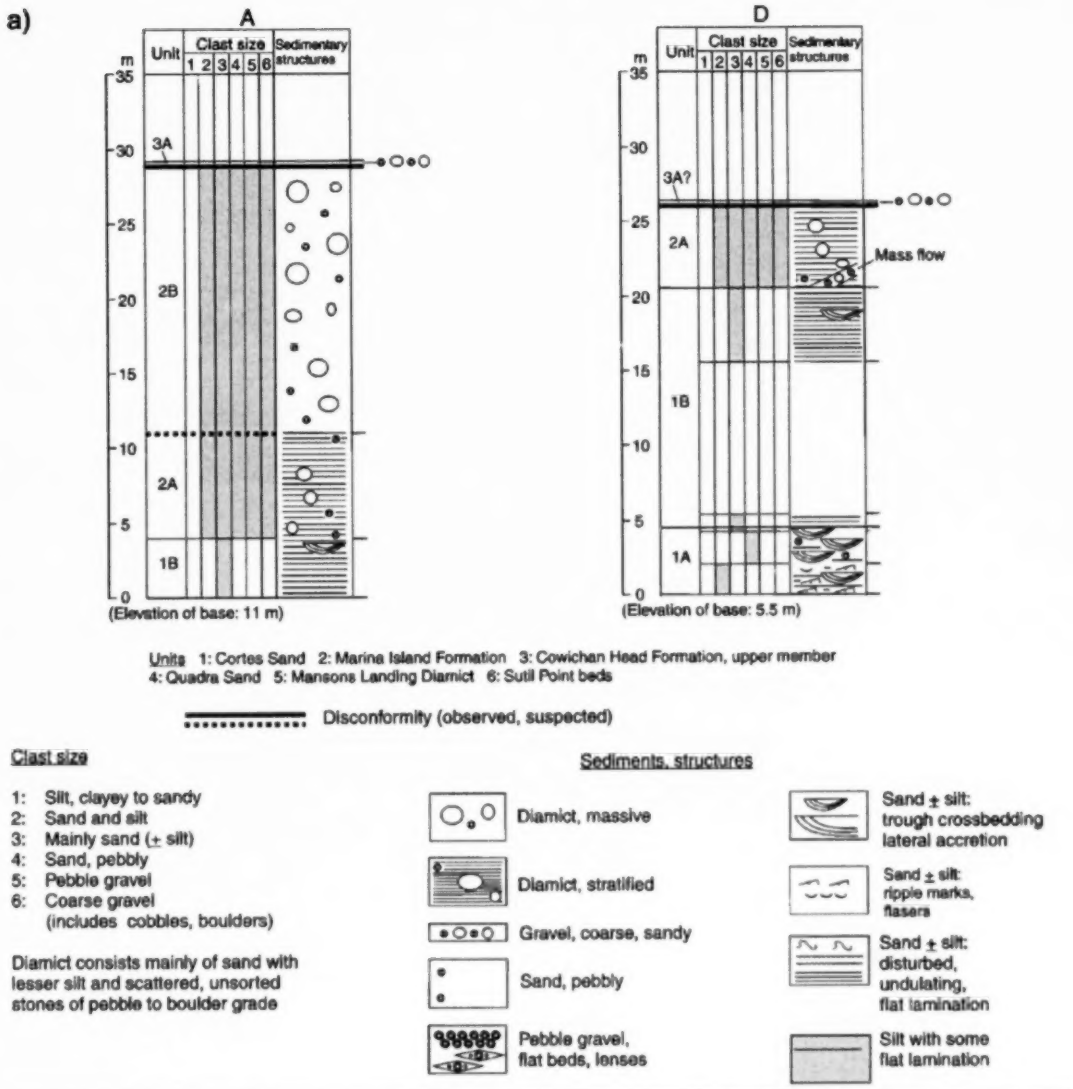

Figure 3a. *Stratigraphic sections of Cortes Sand and Marina Island Diamict.*

STRATIGRAPHY

Stratigraphic sections (Fig. 3) were measured with the aid of a measuring staff and high-precision altimeter. Altimeter readings were calibrated with respect to survey points shown on detailed topographic maps (scale 1:5000) issued by the British Columbia Ministry of the Environment or to the upper limit of beaches, which coincides with the 5 m contour.

The total maximum thickness of the Pleistocene exposures in this area is about 130 m. The succession is subdivided into six major units. Established names are used for two widespread formations, and local names are introduced for the others. For brevity, the units and subunits are labelled by number-letter symbols in the graphic figures and described as such in the final discussion. In addition, three unnamed units (labelled by numbers with asterisks) that have been eroded and are represented only by boulders are discussed.

Cortes Sand (unit 1)

The name Cortes Sand is here given to the oldest Pleistocene formation in the report area, the base of which is concealed. At the type section on southeastern Cortes Island (section D of Fig. 1b, 3) it is 20.5 m thick and conformably overlain by

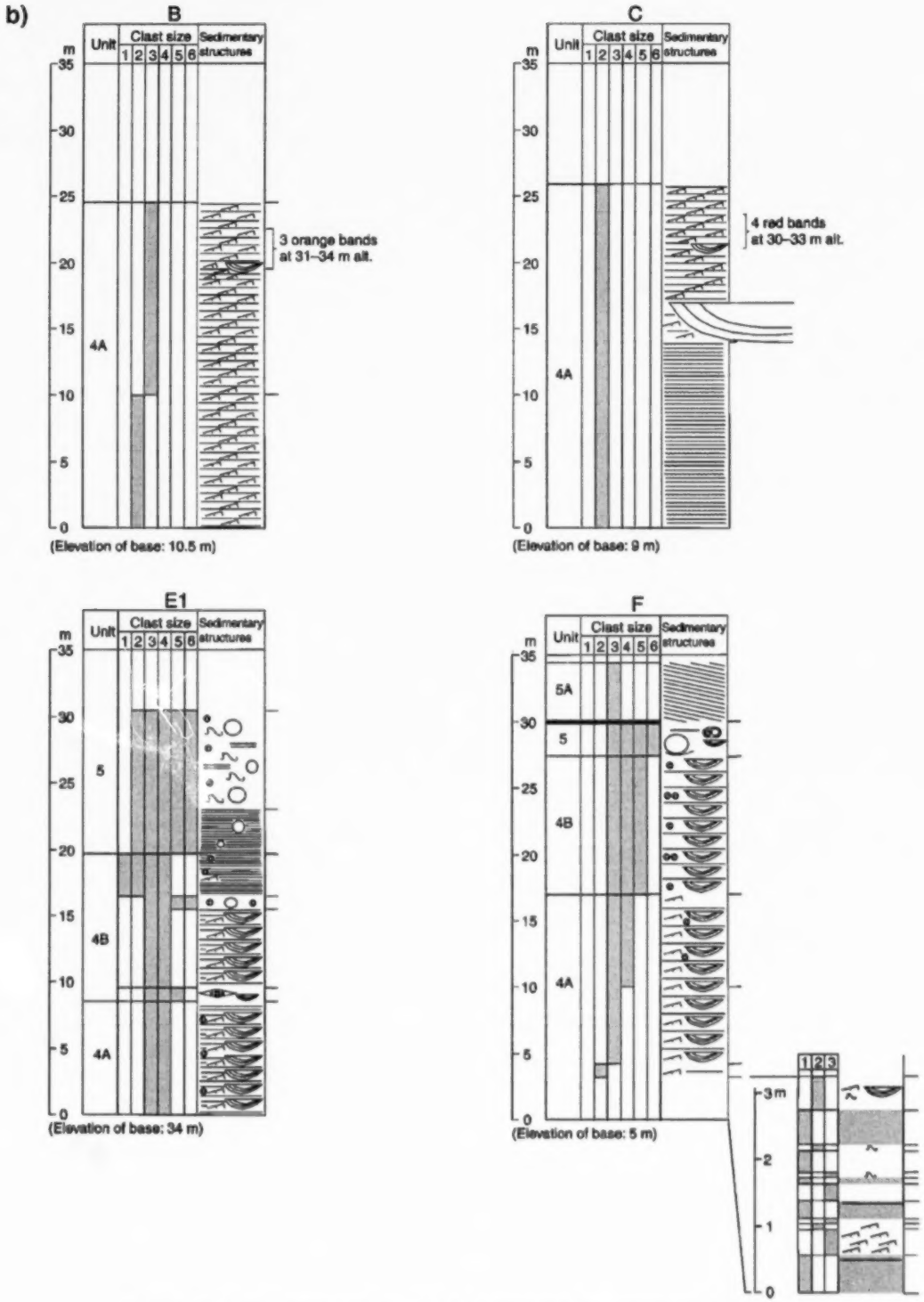

Figure 3b. *Stratigraphic sections of Quadra Sand and Mansons Landing Diamict.*

the Marina Island Diamict. The formation consists largely of sand with minor silt in the lower 2 m and with minor pebbly sand in the following 2 m. The unit is mainly yellowish-grey to light greenish-grey, but also includes some reddish-weathering beds in its lower and middle parts that are stained by limonite derived from weathered pyrite.

Two members, A and B that differ mainly in primary structure and inferred depositional environment are distinguished. Member A (unit 1A), represented by the lower 4.5 m of section D, is dominated by crosslamination, with lesser horizontal lamination, flaser structures, and convolute lamination (Fig. 4a). Sets of crosslaminae are mainly concave and from a few centimetres to about 30 cm thick. These sediments probably were deposited in a high-energy, nearshore environment. Member B (unit 1B), in contrast, is dominated by horizontal lamination with less common ripple marks and trough-crossbeds. It is 16 m thick at section D where it is partly covered. Additional, incomplete exposures occur at section A and at localities e (10 m) and h. The primary structures of this member indicate mainly quiet, subtidal settings. The subsidence indicated by the change in primary structures from member A to member B may reflect an isostatic subsidence caused by the approaching ice load.

The conformable relationship with the Marina Island Diamict implies that the Cortes Sand is an advance deposit of the early Wisconsinan Semiahmoo Glaciation, analogous to the Quadra Sand, which is an advance deposit of the Fraser Glaciation (Clague, 1977). Although different in detail, the Cortes Sand probably is correlative with the Mapleguard Sediments of southern Vancouver Island (Fyles, 1963) interpreted as an advance deposits of the Dashwood Drift by Hicock and Armstrong (1983), but abolished by them as a separate unit and included in the Dashwood Drift. The term Cortes Sand thus fills a vacancy in the regional stratigraphic framework (cf. Clague, 1989, 1991, 1994, 2000).

Marina Island Diamict (unit 2)

The name Marina Island Diamict is here given to glacial deposits lying conformably on the Cortes Sand. At the type locality, section A on the south tip of Marina Island, the formation is 24 m thick, unconformably overlain by the upper member of the Cowichan Head Formation, and divisible into two members, A and B (Fig. 3). At section D only the lower part of member A is preserved.

Member A (unit 2A), 7 m and 5.5 m thick at sections A and D, respectively, consists chiefly of stratified diamict with minor massive diamict and turbidite units. The stratified diamict is composed mainly of flat-laminated sand and minor silt, similar to member B of the Cortes Sand, but it also contains scattered, unsorted stones of pebble to boulder size, interpreted as ice-rafted dropstones. A thin unit of massive diamict, cutting across the stratified diamict of section D, probably represents a mass-flow deposit produced by submarine slumping. Sandy turbidite units (Fig. 4c, d) at locality m, occurring not far above stratified diamict exposed at locality k, probably are distal equivalents of such flows. The turbidite beds represent divisions A to C of the Bouma model (Fig. 4c, d). They range in thickness from 24.5 cm to more than 53 cm, and in grain size from silt to coarse, pebbly sand.

Member B (unit 2B), about 17 m thick at section A, consists of massive diamict. The boundary with member A was inaccessible and its position is uncertain within an interval of about 3 m.

The Marina Island Diamict is correlative with the Semiahmoo and Dashwood drifts of the Fraser Lowland and southern Vancouver Island, respectively (Hicock and Armstrong, 1983), but differs from these two formations in detail. Member A represents glaciomarine sediments deposited when the glaciers had reached tidewater. Member B is probably a lodgement till, formed during the maximum of the Semiahmoo Glaciation. If so, an unconformity should be present at the base of member B, but this has not been confirmed.

Cowichan Head Formation, upper member (unit 3)

The Cowichan Head Formation (Armstrong and Clague, 1977), named for outcrops near Victoria, underlies lowlands adjacent to the Strait of Georgia. Generally less than 10 m thick, it has been divided into two members. The lower member, consisting mainly of sand and mud, is of marine origin and conformably overlies glaciomarine sediments of the Semiahmoo and Dashwood drifts. It is less widely exposed on land than the upper member, which comprises organic-rich gravel, sand, and silt of fluvial and estuarine aspect. Where the lower member is absent, the upper member overlies "an irregular erosion surface developed on older drift" (Clague, 1989, p. 50). "Reliable radiocarbon ages from this unit range from 23.8 to 58.8 ka" (Clague, 1994, p. 187), a relatively warm climatic interlude correlative with the Oxygen Isotope Stage 3 (Olympia Nonglacial Interval).

A poorly exposed unit on Marina Island that unconformably overlies the Marina Island Diamict and is overlain by the Quadra Sand with a covered contact is interpreted as the upper member of the Cowichan Head Formation. This assignment is based mainly on stratigraphic relations and a radiocarbon age. The thickness of the unit (±5 m according to graphic reconstruction; Fig. 1c) and limited information about its lithology are compatible with this interpretation.

Only two beds are known. The basal stratum (bed A, or unit 3A of Fig. 1b, 1c, 2, 3) is exposed at section A and locality a, where it is 0.5 m and 1 m thick, respectively. At both sites it overlies member B of the Marina Island Diamict with an abrupt contact. It is similar to the latter with respect to clast size (mainly pebbles and cobbles with some boulders), composition (mainly granitoid rocks with lesser andesite or basalt), and massive structure, but differs from it by having a much higher proportion of stones versus sandy matrix. The bed probably was derived from the Marina Island Diamict by winnowing of its matrix in a high-energy, nearshore environment during the isostatic rebound that followed the Semiahmoo Glaciation.

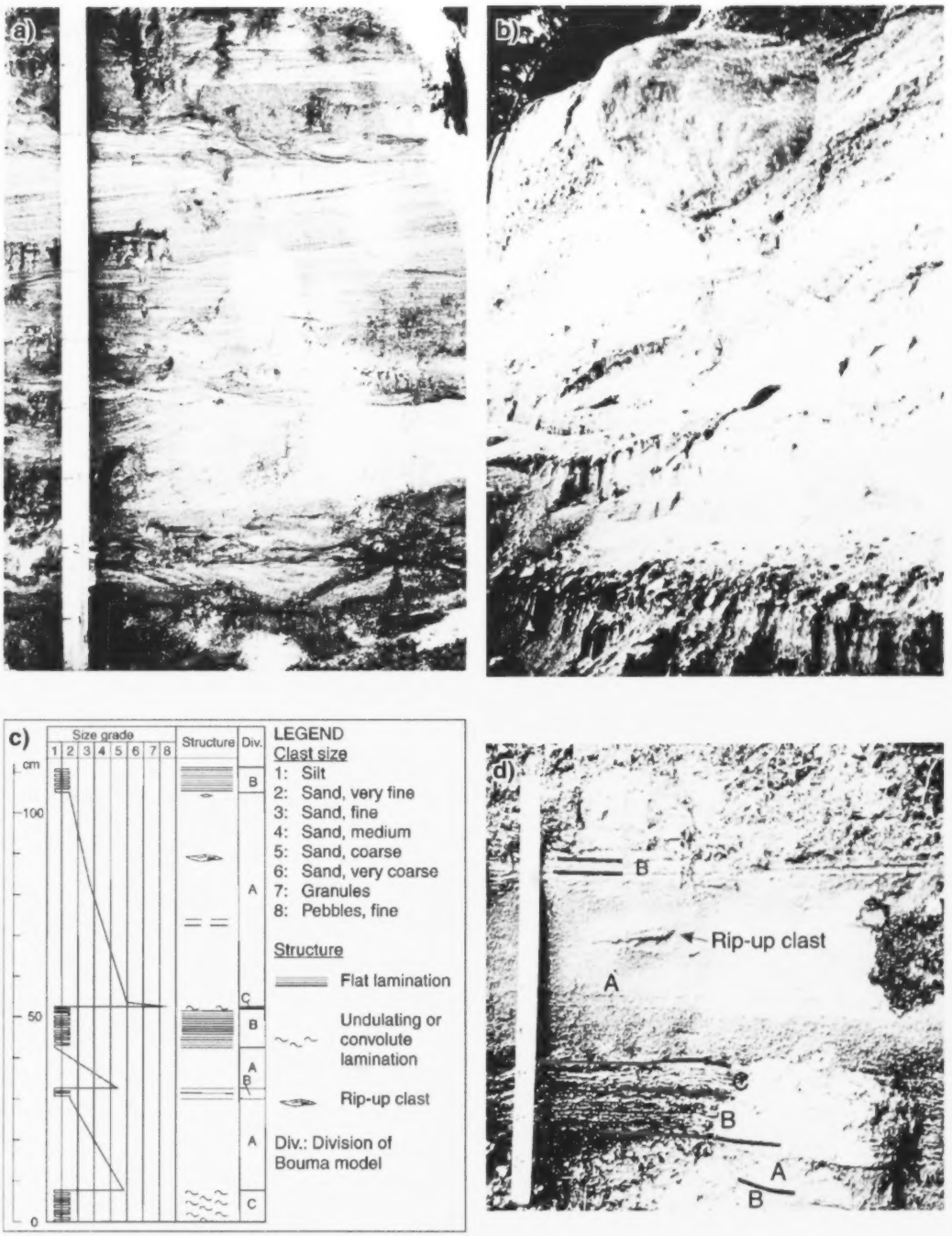

Figure 4. *Advance and glaciomarine deposits* ***a)*** *Cortes Sand, member A, lower 1 m at section D. Crosslamination, horizontal lamination, reactivation surfaces, and flaser structures (at 20 and 42 cm) indicate a high-energy, nearshore environment.* ***b)*** *Upper part of section F. A boulder-sized dropstone (base of Marina Island Diamict) has disturbed horizontal beds of gravel and sand that must be marine (Mansons Landing Diamict, member B). The boulder is about 1 m in diameter (estimate).* ***c)*** *Detailed stratigraphy of turbidite units (Marina Island Diamict, member A) at locality m.* ***d)*** *Middle and upper parts of same section (1 m staff for scale).*

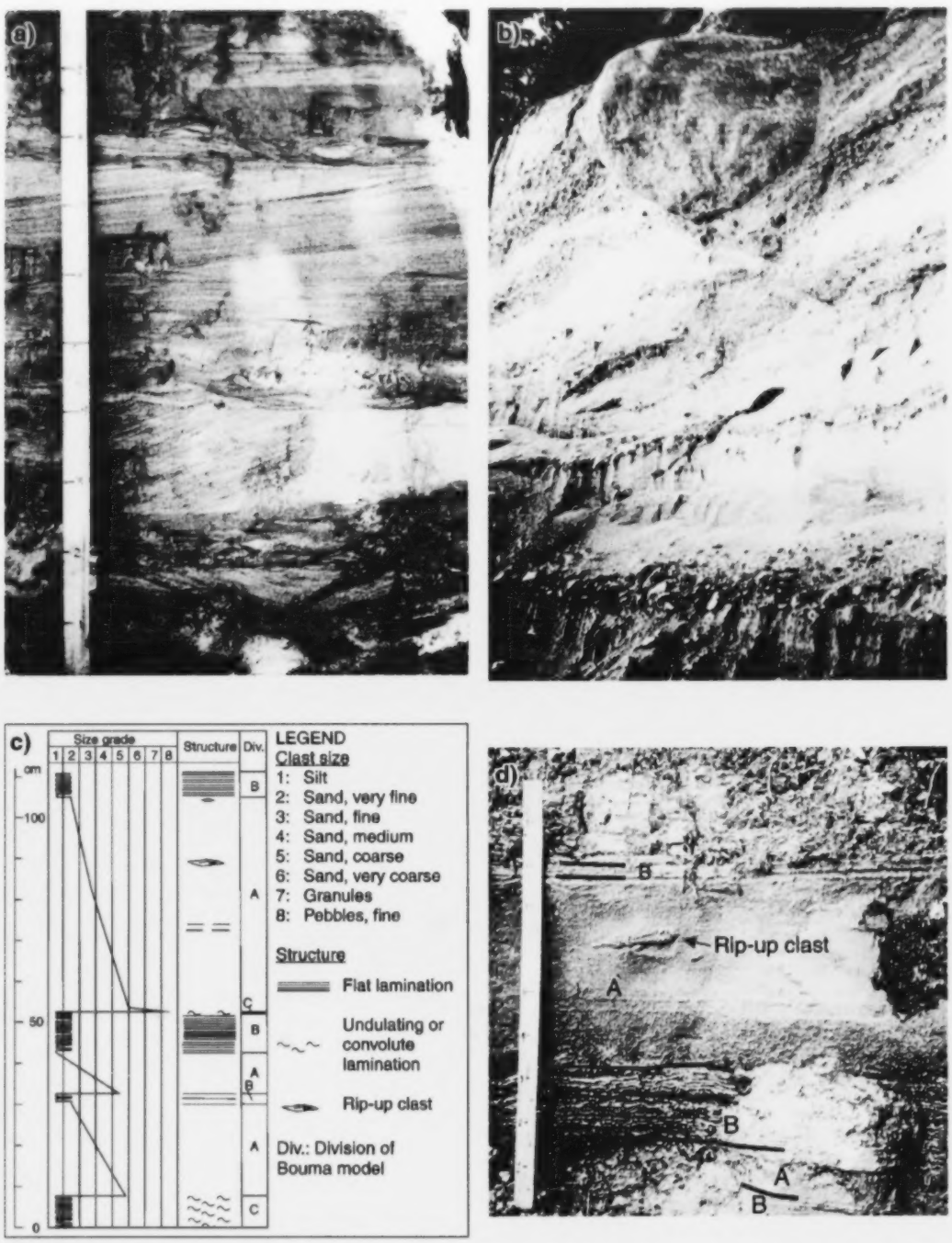

Figure 4. *Advance and glaciomarine deposits* **a)** *Cortes Sand, member A, lower 1 m at section D. Crosslamination, horizontal lamination, reactivation surfaces, and flaser structures (at 20 and 42 cm) indicate a high-energy, nearshore environment.* **b)** *Upper part of section F. A boulder-sized dropstone (base of Marina Island Diamict) has disturbed horizontal beds of gravel and sand that must be marine (Mansons Landing Diamict, member B). The boulder is about 1 m in diameter (estimate).* **c)** *Detailed stratigraphy of turbidite units (Marina Island Diamict, member A) at locality m.* **d)** *Middle and upper parts of same section (1 m staff for scale).*

Between localities a and b, bed A is separated from the Quadra Sand by a thin, covered interval (Fig. 1b, c). Farther northwest on the coast of Marina Island (locality c) a bed of "plant-bearing silt" was discovered by J.G. Fyles "about 3 feet above high tide level" (Olson and Broecker, 1961, p. 147). This outcrop lies in the upper part of the interval and is here referred to as bed B (unit 3B). A piece of pine wood from this stratum, submitted to the laboratories of the Lamont Geological Observatory and the Geological Survey of Canada, yielded apparent ages of 35.4 ± 2.2 ka and 35.4 ± 0.4 ka, respectively (Olson and Broecker, 1961; Table 6 *in* Clague, 1977). When revisited by the author in 2000, the stratification had been obliterated by root growth and no plant-bearing silt was found.

On southern Cortes Island, bed A may be represented by a massive bed of sandy gravel that unconformably overlies member A of the Marina Island Diamict at section D, and member B at locality d. This interpretation is tentative because overlying strata of the Cowichan Head Formation and of the Quadra Sand are not preserved at these localities.

Quadra Sand (unit 4)

The Quadra Sand, a widely distributed Pleistocene formation in the Georgia Depression, has its type section on southern Quadra Island (Clague, 1977). It overlies mainly the Cowichan Head Formation, but also older sediments or bedrock, and is overlain by glaciomarine or glacial deposits. The formation consists chiefly of light-coloured sand that is generally well sorted and commonly crosslaminated, with lesser proportions of silt and gravel. Organic material is very rare. The contact with the Cowichan Head Formation is sharp and readily determinable by lithological criteria. Recorded thicknesses locally exceed 50 m (Clague, 1989). Radiocarbon ages range from about 19 ka to 29 ka and overlap with the oldest radiocarbon ages from the Cowichan Head Formation (cf. Table 6 *in* Clague, 1977). The Quadra Sand clearly is a diachronous unit, deposited in front of glaciers, which, after emergence from the Coast Mountains, flowed down the axis of the Georgia Depression in a southeasterly direction (Clague, 1977).

In the study area, the Quadra Sand lies between the upper member of the Cowichan Head Formation and the Mansons Landing Diamict. The lower contact, as mentioned, is concealed, but probably lies only a few metres below sections B and C. The nature of this contact is problematic, an unconformity cannot be ruled out. The upper contact, exposed at sections E1, E2, and F, is conformable. In the most complete exposures, the thickness ranges from 27.5 m (section F) to about 48 m (section E2). The formation is divisible into two members, distinguished by the presence or absence of gravel.

Member A (unit 4A) is composed mainly of sand with interbedded silt in the lower part and minor pebbly sand in the uppermost part. Measured thicknesses of this incompletely exposed unit range from 17 m at section F to 30 m at section E2. Comparison of stratigraphically equivalent sections reveals considerable variations in sand/silt ratio and primary structures. Silt and sand both show horizontal lamination and ripple marks. Sand, in addition shows trough-crossbedding — abundant at section F and rare at section B. Less common are convolute lamination, slump structures (at section F), and lateral accretion-type crossbedding (at section C).

Member B (unit 4B) consists of interbedded sand and gravel. Silt and minor mud, partly dark grey, occur in the upper part of sections E1 and E2, but are absent from section F. The thickness of the member is 10.5 m at section F, 11.5 m at E1, and 17 m at E2. Sand and gravelly sand show both horizontal bedding and crossbedding, whereas gravel occurs mainly as lenticular or tabular bodies. Typical gravel beds at section E1 are 10–70 cm thick.

Environment of deposition

The Quadra Sand in this area is an upward-coarsening succession that reflects sedimentary progradation, caused by a glacial advance, into a shallow marine basin. The bulk of the formation probably represents a variety of delta-front settings with the crossbedded sands indicative of high-energy, nearshore environments. Tidal features are not obvious although lateral accretion-type crossbedding at section C may have originated in a meandering tidal channel. The crinkled lamination in the lower part of that section suggests sliding (without disaggregation) on a slightly inclined subaqueous slope.

Lenticular gravels in the lower part of Member B at sections E1 and E2 are suggestive of a braidplain environment. The upper part of the same member, however, must be of subaqueous origin because it is similar to the matrix of the ice-rafted dropstones of the Mansons Landing Diamict (Fig. 4b). The subsidence apparent at this level may again reflect crustal subsidence under an approaching ice load, as inferred for the Cortes Sand.

Mansons Landing Diamict (unit 5)

The name Mansons Landing Diamict is here proposed for a stratified diamict that conformably overlies the Quadra Sand. The type section is at section E1, 1 km southwest of the Mansons Landing dock. There it is about 11 m thick and forms a vertical cliff, accessible only in the lower few metres. The matrix of the diamict consists of thinly interstratified sand, pebbly sand, and dark grey mud, similar to the uppermost part of the Quadra Sand. The lower part shows horizontal lamination with some ripple marks; the upper part shows soft-sediment deformation. Scattered throughout this matrix are unsorted pebbles, cobbles, and boulders. At section E1 the formation is overlain by limonite-stained gravel and sand that represents the B-horizon of a soil profile. About 4 m of similar strata are exposed at section E2, about 0.8 km southwest of Mansons Landing.

At section F, on northwestern Hernando Island, the diamict is only about 2.5 m thick (Fig. 4b). The matrix consists of thinly bedded sand, gravelly sand, and pebble gravel, again similar to the underlying Member B of the Quadra Sand.

Stratification is roughly horizontal, but disturbed. Unsorted pebbles, cobbles, and small boulders, as well as an isolated large boulder, are scattered through this matrix.

The coarse size and scattered, unsorted distribution of the stones in the Mansons Landing Diamict indicates that they were dropped from melting or overturned ice rafts in offshore settings. The presence of dark grey silt and mud at sections E1 and E2 suggests poorly oxygenated waters, probably deeper than those at section F. The soft-sediment deformation structures at sections E1 and E2 are due to slumping, whereas those at section F may be due to the impact of dropstones.

Spilsbury beds (subunit 5A)

This subunit comprises an estimated 4–5 m of light grey, planar-laminated sand that overlies the Mansons Landing Diamict in a steep, inaccessible cliff at the top of section F near Spilsbury Point. The abruptness of the contact probably indicates an unconformity, but in the absence of a gravel lag, there is no sign of intervening erosion. A beach environment of deposition is tentatively inferred from the planar lamination of the sand, which seems to be slightly inclined with respect to the basal contact, and from its light tone. Considering the thin development of the underlying dropstone-bearing sediments, the Spilsbury beds can be regarded as an uncharacteristic, local facies within the same formation (Mansons Landing Diamict).

Smelt Bay beds (unit 8)

The informal name, Smelt Bay beds, is here used for deposits of gravel, sand, and minor silt that are overlain by a boulder lag (unit 9*). Scattered exposures occur at a few localities east and north of Smelt Bay. Pelecypod shells have been obtained from two of these exposures by T.S. James (pers. comm., 2003) and co-workers, and their radiocarbon ages are cited here along with information about the depositional environment of the collections.

The base of the unit has not yet been discovered. The topographically lowest outcrop, at locality g near Sutil Point Road (elevation 42 m), consists of about 1 m of flat-bedded pebble gravel, pebbly sand, and sand. Red and brown colours indicate the B horizon of a podzol soil profile.

At locality j (elevation 46.5–48 m) about 1.5 m of slightly inclined strata are exposed on the rim of a shallow pit. They consist mainly of sandy pebble gravel, light grey or brown, with 20 cm of interbedded, vaguely laminated, light grey sand. Shells, recovered earlier from underlying beds that are now concealed (E. Piggot, pers. comm., 2001), have yielded a radiocarbon age of 11.8 ± 0.1 ka (reservoir correction: – 800 years). These strata may represent a mass flow because the shell assemblage suggests a relatively deep environment.

A gravel pit at locality f (elevation 48–62 m) exposes about 14 m of pebble- to cobble-sized gravel and lesser sand. The lower 1.2 m consists of two units of partly graded gravel, separated by a gently inclined bed of planar-laminated sand. Shell fragments from the upper gravel have yielded a radiocarbon age of 11.3 ± 0.1 ka. The shells suggest a shallow-water environment but clearly are not in place and probably were transported downslope. Foresets of thinly interbedded pebbly sand and pebble gravel, exposed near the top of the pit, have a persistent, steep, south-southwesterly dip.

At locality o (elevation 58–60 m) similar foresets are exposed, which, however, dip steeply southeast. They consist of interbedded gravelly sand, sand, and laminated silt. Soft-sediment deformations and thin mass flows indicate a subaqueous setting.

In summary, the Smelt Bay beds have a minimum thickness of 20 m and a minimum age range from 11.8 ka to 11.3 ka. The sediments were deposited on subaqueous deltas where mass flow occurred. The clastic material probably was inherited from the Cordilleran Ice Sheet and transported by streams issuing from remnant glaciers, now vanished, in the hills of central Cortes Island.

Eroded diamicts, probably represented by boulders (units 6, 7*, and 9*)*

The study area is littered with boulders that are erosional remnants of probably five different units, but can be related to their sources at a few localities only. Boulders are especially abundant on the tidal flats and many of these must be relics of the Marina Island and Mansons Landing diamicts. Relics of three unnamed, younger diamicts are probably present both on the tidal flats and on the elevated plain of southern Cortes Island.

Units 6* and 7*

Following the glaciomarine phase of sedimentation represented by the Mansons Landing Diamict, the Georgia Depression was invaded by the Cordilleran Ice Sheet, which caused deep erosion and left a major till (unit 6*). When the ice melted and the sea returned, another set of glaciomarine sediments with dropstones (unit 7*) was laid down. Both units are known from subsea investigations in the strait (Barrie and Conway, 2000), but seem to have been eroded in the study area. If so, they must have left two superimposed boulder lags that could not be distinguished from each other. A dense cluster of boulders (up to 2.6 m in diameter) and cobbles at locality q is a possible example. It occurs about 225 m southeast of the top of section E1, at an elevation of 77 m, 11 m above the top of the Marina Island Diamict.

Unit 9*

Scattered stones overlie the soil formed in the upper 1–2 m of unit 8 at localities g and o. Boulders (up to 1.5 m in diameter) are most conspicuous, but cobbles and pebbles are also present. These stones are interpreted as the lag of a glaciomarine diamict, winnowed at shallow water depth during isostasy-driven emergence. An alternative interpretation of the stones, lag of a till, would imply a more extensive readvance that is not supported by information from other parts of the Georgia Depression (Barrie and Conway, 2000; James et al., 2002).

SOURCES, COMPOSITION, AND INDURATION OF SEDIMENTS

The orientation of inlets and channels in the vicinity of Cortes Island shows that glaciers flowed down the southwestern slope of the Coast Mountains and were deflected to the southeast in the Georgia Depression (Fig. 2 *in* Clague, 1994). The composition of the Wisconsinan sediments is compatible with derivation from the southwestern Coast Plutonic Complex. Stones in gravels and diamicts consist mainly of granitoid rocks with less abundant, darker, dyke rocks and volcanic rocks. The surficial stones are similar, but also include metamorphic and sedimentary rocks. Sandstone clasts containing Lower Cretaceous pelecypods were derived from the Gambier Group (Haggart, 1995; Gronau, 2002; C.W. Gronau, unpub. manuscript, 2002).

Sands of different units (examined in smear slides and by X-ray diffraction) are comparable in mineral composition to the granitoid rocks (cf. Clague, 1977). They consist mainly of quartz, plagioclase, and K-feldspar, with lesser biotite, hornblende, and magnetite. Some strata also contain pyrite, commonly weathered to limonite.

Most sediments are loose with two exceptions. Silty strata of the Marina Island and Mansons Landing diamicts exposed to water are plastic or solid, owing to cementation by clay minerals. Sand and gravel of other units, lying in B-horizons of the podzol soil profile, are locally indurated by limonite.

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